U.S. DEPARTMENT OF ENERGY

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CD-1 Closeout by the Review Committee for the

LHC CMS Detector Upgrade Project

Fermi National Accelerator Laboratory

August 27, 2013

Kurt Fisher
Review Committee Chair
Office of Science, U.S. Department of Energy
http://www.science.doe.gov/opa/

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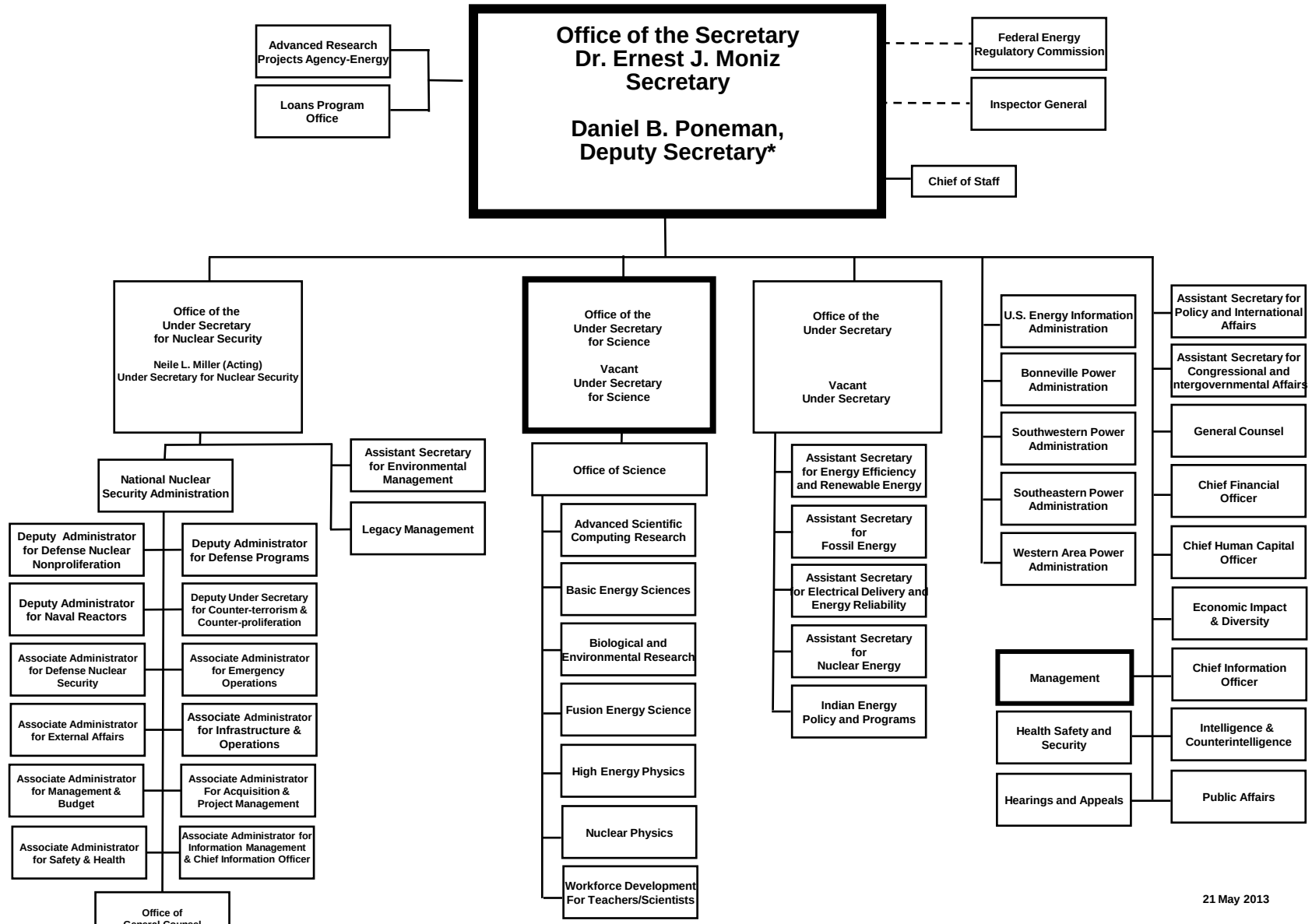
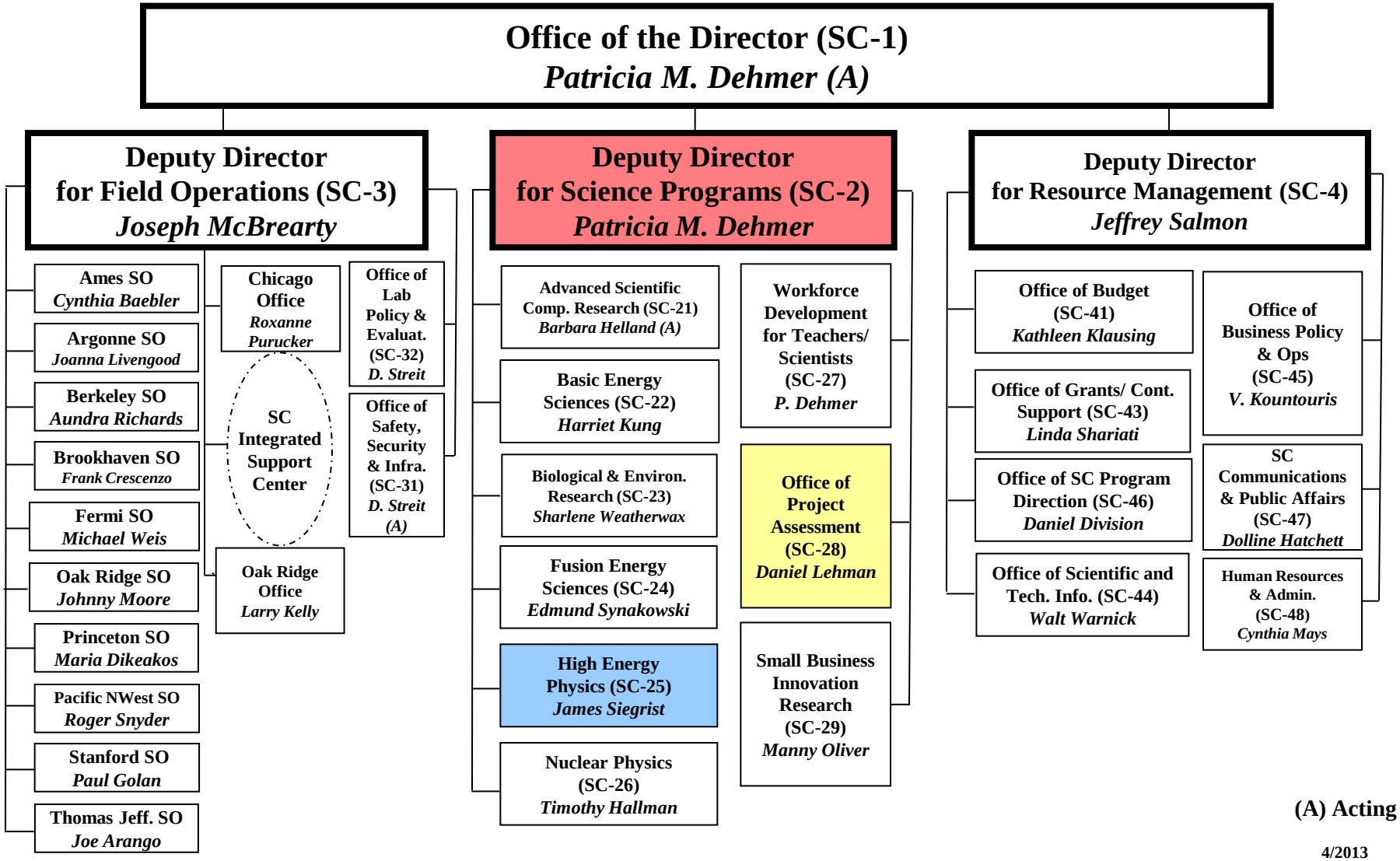


21 May 2013

*The Deputy Secretary also serves as the Chief Operating Officer.

SC Organization



(A) Acting

4/2013

Review Committee Participants

Kurt Fisher, DOE/SC, Chairperson

SC1
HCal—Hadron Calorimeter (WBS 1.2)

Jim Proudfoot, ANL
Jim Pilcher, U. of Chicago

SC2
Forward Pixel Detector (WBS 1.3)

* Jim Brau, Oregon
Maurice Garcia-Sciveres, LBNL

SC3
Level 1 Trigger (WBS 1.4)

* Myron Campbell, U. of Michigan
Charlie Young, SLAC
Luciano Ristori, FNAL

SC4
Cost and Schedule

Ethan Merrill, DOE/SC
Gail Penny, DOE/BHSO

SC5
Project Management (WBS 1.1)

* Mark Reichanadter, SLAC
Michael Levi, LBNL
Mark Palmer, FNAL

Observers

Jim Siegrist, DOE/SC
Mike Procario, DOE/SC
Simona Rolli, DOE/SC
Pepin Carolan, DOE/FSO
Steve Webster, DOE/FSO

LEGEND

SC Subcommittee
* Chairperson

Count: 13 (excluding observers)

Charge Questions

1. Conceptual Design: Is the conceptual design sound and likely to meet the MIE project's technical performance requirements most efficiently and effectively? Do the conceptual design report and supporting documentation adequately justify the stated cost range and project duration?

2. Project Scope: Are the project's scope and specifications sufficiently defined to support preliminary cost and schedule estimates?

3. Cost and Schedule: Are the cost and schedule estimates credible and realistic for this stage of the project? Do they include adequate scope, cost and schedule contingency?

4. Management and ES&H: Is the project being appropriately managed at this stage? Does the proposed project team have adequate management experience, design skills, and Laboratory support to produce a credible, technical, cost and schedule baseline? Are ES&H aspects being properly addressed and are future plans sufficient given the project's current stage of development?

5. Documentation: Is the prerequisite documentation required for approval of CD-1 complete?

Report Outline/ Writing Assignments

*Lead
SC Subcommittee

Expectations

- **Forward your sections for each review report (in MSWord format) to Casey Clark, casey.clark@science.doe.gov,**

  by September 3, 8:00 a.m. (EDT).

2.1 Hadron Calorimeter (WBS 1.2)

J. Proudfoot, ANL*, Jim Pilcher, UofC / SC1

1.)Conceptual Design: Is the conceptual design sound and likely to meet the MIE project's technical performance requirements most efficiently and effectively? Do the conceptual design report and supporting documentation adequately justify the stated cost range and project duration?

YES, Replacement of the present photo-sensors with SiPMs allows increased granularity the HCAL readout of the HBHE within the physical, optical and services constraints in the existing detector. The QIE10/QIE11 readout chip provides improved precision, sufficient dynamic range and 0.5ns signal timing to allow identification of background signals

2.)Project Scope: Are the project's scope and specifications sufficiently defined to support preliminary cost and schedule estimates?

YES – KPPs are well defined. Project cost and contingency is appropriately estimated; contingency is at a level associated with a conceptual design at 31% of the base cost. Schedule has 1 year of float in advance of production start but minimal float in the production phase

2.1 Hadron Calorimeter (WBS 1.2)

J. Proudfoot, ANL*, J. Pilcher, UofC / SC1

1.Findings

The CMS HCAL Upgrade is proposed to:
Allow the HB/HE calorimeter system to continue to perform at high efficiency in the expected higher than design luminosity of the LHC by replacing the current photosensors by SiPMs, and increasing the readout granularity and providing signal timing to mitigate the impact of pileup.

Mitigate the impact of radiation damage to the calorimeter scintillator for an integrated luminosity of 500fb-1by providing increased depth granularity and mip calibration to allow correction of the scintillator response as a function of time/dose.

Address backgrounds associated with the current photo-sensors and the sensitivity of the HPD to magnetic fields by replacing them with Silicon Photomultipliers.

Solve the problem of low and unstable gain in the present photo-sensors.

<u>Documentation</u>: Is the prerequisite documentation required for approval CD-1 complete? Yes. BASICALLY IN GOOD ORDER – but needing refinements.

CDR is presently in draft form and should be finalized

BoE does not provide unit counts for deliverables at appropriate BoE Level (generally level 3, but Level 4 for SiPMs for example)

- **Comments**

  SiPMs are recently developed devices which have not been widely used in high radiation environments. USCMS has done extensive testing and the results appear very promising. A number of vendors are available and the performance of their devices continues to improve but is already at an acceptable level.

  It will be important to complete the planned test of a full Readout Box in the CERN IRRAD facility with both neutrons and hadrons. Monitoring the stability of the signal from a laser light pulser is planned and is an essential part of this test. It is important that this test cover the MIP signal region to insure the in situ calibration capability of HB/HO.

  It will also be important to complete the tests of a section of the calorimeter using these devices as planned at CERN in July 2015.

- **Comments**

  The QIE design is in advanced state of development and an experienced team is in place to oversee production and testing. The QIE10 and QIE11 production schedule is delayed by over a year following the ESR. This introduces the possibility that the fabrication process may no longer be available. The collaboration should monitor this situation closely and consider options to mitigate this risk.

  The current HCAL design uses a gigabit transceiver chip (GBTX) designed by CERN. HCAL appears to be the only CMS detector system using this chip and delays in the schedule have already been encountered. This work needs to be closely monitored and alternatives considered.

  It appears difficult to reduce the HCAL upgrade cost without increasing the risk. There are a number of foreign collaborators associated with the work and one option would be to transfer scope to them. This has international complications and alternative risks.

- **Comments**

  The planned system test in a high radiation environment is presently planned for summer 2015. This appears compared for the planned construction start date. The collaboration should consider options for moving up this test.

Recommendations

- For CD-1: Include unit counts for deliverables in BoE text narrative at Level 3
- For CD-1: Finalize CDR
- For CD-2: Work with US-CMS management to develop adequate schedule float in construction phase

1. Conceptual Design:

   Is the conceptual design sound and likely to meet the MIE project's technical performance requirements most efficiently and effectively?

   Given the performance objectives, yes.

   Do the conceptual design report and supporting documentation adequately justify the stated cost range and project duration?

   The US CDR is drawn from the CMS TDR and justifies cost and duration.

2. Project Scope:

   Are the project's scope and specifications sufficiently defined to support preliminary cost and schedule estimates?

   YES

3. Documentation:

   Is the prerequisite documentation required for approval CD-1 complete?

   The technical details – YES

- **Findings (1)**
  - Without upgrades, the current CMS Pixel Detector will continue to lose efficiency following LS1 when the LHC luminosity exceeds 10^{34} cm^{-2} s^{-1}, seriously impacting physics performance.
    - track seeding, primary and secondary vertex reconstruction, and b-tagging will all be degraded.
  - Performance and physics studies have evaluated the potential of an upgrade for the full pixel system, barrel and forward. The impact of a new BPIX inner barrel chip, currently under development, was not presented.
  - The CMS Collaboration has developed an upgrade design to address this degradation, which is documented in the CMS technical proposal for an upgrade pixel system; the US CDR for the forward pixel (FPIX) upgrade is based on this.
  - The upgrade FPIX project involves only US collaborators, no non-US; however, the project relies on CERN support for aspects that are contributed at no cost to the US.
  - The FPIX project relies on PSI to supply the Pixel Readout Chip as well as test setups brought to Fermilab.

- **Findings (2)**
  - The upgraded FPIX implements significant cost reduction measures over the original detector, such as using a single module everywhere, going to 6 inch wafers, and using a cost effective US bump bonding vendor.
  - The upgraded FPIX system comprises 44 million pixels on 672 modules, mounted on 12 half-disks; the upgrade increases the track layers from 3 to 4.
  - Schedule is designed for installation in March 2017. However, some component purchases are delayed to FY16 by limited funding in FY15, compressing schedule and reducing floats.
  - The FPIX installation goal is March, 2017, during proposed (not yet officially approved and scheduled) Extended Technical Stop.
  - A pilot run involving eight modules will be installed in 2014-15, too late to inform the production, but early enough to shake down aspects of the installation and commissioning of the project in 2017.

- **Findings (3)**
  - The project management did not initially present possible areas of scope contingency, but in break out discussions possible scope contingency items were identified.
  - Risk analysis presented identifies three risks to the project. Several other risks have been considered and consolidated in this shortened list.

- **Comments**
  - The FPIX team brings a large experience base to the project based on their role in the original CMS pixel project.
  - Given the performance objectives, scope is appropriate and conceptual design is complete. We look forward to further performance studies, particularly with the new inner barrel BPIX chip included. The FPIX performance margin is not completely clear presently.
  - The design is well documented in the conceptual design report with reasonable cost estimates.
  - Building in scope contingency may have an impact on the half disk and half cylinder assembly sequences.
  - During review additional risks beyond those presented were identified.
  - Even though the number of spares is large, the module yield assumption (85%) is aggressive.
  - Qualification period for pre-production modules in 2015 (approximately 2-3 months) is not currently shown in the schedule.
  - Delayed purchase of components due to limited funding in FY15 adds schedule risk.

- **Recommendations**
  - Plan to advance component purchases by applying contingency when it becomes available to in order to protect schedule float.
  - Consider using a more conservative module yield assumption.
  - Add to schedule an explicit qualification time for the first batch of module production.
  - Consider exchanging flip-chip assemblies with European BPIX colleagues to assemble FPIX modules using BPIX flip chip assemblies in the module production ramp-up stage, and vice-versa.
  - Broaden risk analysis to ensure comprehensive understanding. For example, what if the pilot run reveals needed minor hardware modifications, or …?

  - **The Forward Pixel Detector project is ready for CD-1 approval.**

1. Conceptual Design: Is the conceptual design sound and likely to meet the MIE project's technical performance requirements most efficiently and effectively?
   YES
   Do the conceptual design report and supporting documentation adequately justify the stated cost range and project duration?
   YES
2. Project Scope: Are the project's scope and specifications sufficiently defined to support preliminary cost and schedule estimates?
   YES
5. Documentation: Is the prerequisite documentation required for approval CD-1 complete?
   YES

2.3 Level 1 Trigger

- **Findings**
  - The Level 1 Trigger Upgrade is needed to respond to the increase in luminosity, the increase in energy, and the increase in number of events per crossing (Pile-up)
  - There are two major components to the Level 1 Trigger Upgrade. The first is to increase the momentum and angular resolution of the muon trigger and the second is to increase the processing granularity of the calorimeter trigger.
  - The phased approach to allow simultaneous operation of the current system and the new system mitigates many potential risks. There was not any significant increase in cost due to this concept.
  - Prototypes for all major boards have been made.

2.3 Level 1 Trigger

- **Comments**
  - In the plenary session presentation one of the issues identified with higher luminosity was the increased rate of single event upsets. While the ability to directly reduce SEU's is outside the scope of this project, they have adequate plans for detecting and mitigating the effects of SEU's.
  - The infrastructure needed to build and test the electronics at each institution is well matched to the task. The number of boards and crates is matched to the test stand needs.
  - The performance of the Trigger system has been adequately measured with a combination of data from high intensity special runs and validated monte carlo simulation.
  - Legacy computer support to ensure that design tools are available for the duration of CMS operation need to be implemented.

- **Recommendations**
  Proceed to CD-1

1. Conceptual Design: Is the conceptual design sound and likely to meet the MIE project's technical performance requirements most efficiently and effectively? Do the conceptual design report and supporting documentation adequately justify the stated cost range and project duration? **YES**

2. Project Scope: Are the project's scope and specifications sufficiently defined to support preliminary cost and schedule estimates? **YES**

3. Cost and Schedule: Are the cost and schedule estimates credible and realistic for this stage of the project? Do they include adequate scope, cost and schedule contingency? **YES**

5. Documentation: Is the prerequisite documentation required for approval of CD-1 complete? **YES**

Findings

- The project has prepared a detailed resource-loaded schedule with 2,243 activities and 428 milestones to achieve the project scope and includes NSF activities.
- The project schedule includes 14 months of schedule contingency to CD-4 (~25%) as well as at least 6 months float to the needed by dates at CERN. L3 milestones include 3 months of float and L2 milestones include 6 months.
- Subproject schedules and critical paths are largely independent with a link at CD-3 and two linkages between HCAL and Trigger.
- The proposed CD-1 cost range is $29.2M-$35.9M. The preliminary DOE total project cost is $33.2M including $6.213M estimate uncertainty contingency and $2.4M risk-based contingency. Total project contingency is approximately $9M (~39% of to-go costs).
- The base estimate is 48% materials and services and 52% labor
- The project includes $923K in scope contingency associated largely with the objective Key Performance Parameters. Other opportunities were identified during the review.
- The NSF contribution is estimated at $13.5M based on the proposal.
- Institution specific escalation rates are under negotiation.

Comments

- The cost contingency is time-phased in the project schedule and appears reasonable at 39% of to-go costs. FY 2014 contingency appears low at 18%.
- The cost estimate is sufficiently detailed and mature for this stage of the project. The BOE needs to be reviewed to ensured that all backup is included. A sampling indicated some material quantities were not included.
- The schedule contingency appears reasonable for this stage of the project.
- The preliminary resource loaded schedule is well-developed and detailed but appears sub-optimized due to funding constraints.

Recommendations

- Prior to CD-1, review the BoEs to ensure quantities are accurate.
- Proceed to CD-1.

PROJECT STATUS		
Project Type	MIE	
CD-1	Planned: FY14Q1	Actual:
CD-2	Planned: FY14Q2	Actual:
CD-3	Planned: FY14Q4	Actual:
CD-4	Planned: FY20Q1	Actual:
TPC Percent Complete	Planned: 5 %	Actual: 5 %
TPC Cost to Date	$ 1.25M	
TPC Committed to Date	$ 1.375M	
TPC	$ 33.25M	
TEC	$ 25.75M	
Contingency Cost (w/Mgmt Reserve)	$ 9.0M	39 % to go
Contingency Schedule on CD-4b	14 months	25 %
CPI Cumulative	N/A	
SPI Cumulative	N/A	

2. Project Scope: Are the project's scope and specifications sufficiently defined to support preliminary cost and schedule estimates?

   Yes, project scope and specifications are quite advanced and adequately support the preliminary cost and schedule estimates.

4. Management and ES&H: Is the project being appropriately managed at this stage? Does the proposed project team have adequate management experience, design skills, and Laboratory support to produce a credible technical, cost and schedule baseline? Are ES&H aspects being properly addressed and are future plans sufficient given the projects current stage of development?

   Yes, the project is appropriately managed by an experienced team. ES&H requirements for CD-1 approval are in place. Yes, future plans are sufficient given the current stage of development.

5. Documentation: Is the prerequisite documentation required for approval of CD-1 complete?

   Yes, all required CD-1 documentation was available for review. Some revisions are suggested in the body of this report. The project team should update documentation in preparation for CD-1 approval.

- **Findings**
  - The US CMS Upgrade Project is part of a larger multi-national upgrade of the CMS Detector to address increasing demands for LHC luminosity and "pileup".
  - The Project scope includes upgrades to three subsystems; Hadron Calorimeter, Forward Pixels and Trigger, jointly funded by DOE (MIE) and NSF (CA).
  - A Joint Oversight Group (JOG) has been established to coordinate shared DOE and NSF responsibilities.
  - An Integrated Project Team IPT has been in place since December 2012 and meets biweekly.
  - The US CMS Preliminary PEP has been drafted and includes a defined set of threshold KPPs (minimum) and Objective KPPs (desired).
  - Fermilab is the lead US lab responsible for the coordination of ~30 US universities.
  - US CMS Project Manager, and Deputy Project Manager, plan to transition out of their positions after CD-1. Fermilab has recently hired a new US CMS Project Manager who will transition into the lead role, and a Deputy Project Manager is being recruited.. Aaron Dominguez (NSF-funded) will continue to serve as Deputy Project Manager in direct charge of the NSF contributions.

- **Findings**
  - A 5-year NSF proposal for $13.5M have been submitted for the Phase-1 Upgrades of the FPIX, HCAL and Trigger and is under review.
  - All documentation necessary for CD-1 approval were available for review by the committee, including, but not limited to;
    - Risk Management Plan and Risk Registry.
    - ES&H Plan and Integrated Safety Management
    - All necessary NEPA documentation.
  - Critical documentation is controlled via CMS document management system (docdb).

- **Comments**
  - The technical design of the US CMS Upgrade Project is well advanced, in most cases beyond CD-1 maturity. The design provides a good basis for establishing cost and schedule range, and therefore a good foundation for proceeding to CD-1 approval.
  - The US CMS Team has excellent management experience and skill level and is capable of producing a technical, cost and schedule baseline.
  - Project governance in terms of technical specifications and lab-university should be discussed in more detail at CD-2.
  - The project objectives developed in coordination with the international CMS collaboration are very specifically defined. No substantive cost descope options were provided by CMS.
  - The Project's KPPs (both objective and threshold) require optimization between CMS requirements, the US CMS Operations Program and the Project, which may not be ideal as currently defined (particularly in Trigger and HCAL).
  - The PEP describes system and value engineering processes, which do not reflect actual CMS practice. Consider implementing whatever system and value engineering processes are described then document the processes being performed.

- **Recommendations**
  - Prior to CD-2, work closely with DOE and NSF and CMS, to refine Project's KPP's to find the appropriate balance between the US CMS Upgrade and US CMS Operations.
  - Prior to CD-2, work closely with DOE and NSF, in considering a split CD-3a/b so that long-lead procurements can be ordered early while the final design continues OR, in the case that the designs are all well in hand, a combined CD-2/3 to ensure the same.
  - Prior to CD-2, update the governance plan for the scientific workforce (as needed by the project), and Partner/University oversight in the PMP.
  - Prior to CD-2, consider updating the PEP to address comments on value engineering and system engineering.
  - Prior to CD-2, the Bases of Estimates (BoE's) should be revisited to:
    - adequately address the complexities of the respective product at each level of integration.
    - allow for potential volatility in manufacturing costs (particularly in out-years)

- **Recommendations**
  - Prior to CD-1, update CD-1 documentation to reflect recommendations of this report as well as typographical errors (e.g. Table 1 of the PMP). Finalize the CDR.
  - Proceed to CD-1 approval.